

# ESO540-032: a Transition-Type Dwarf in the Sculptor Group

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## 1 Introduction

The *dwarf Irregular* galaxies (dIrr) are gas-rich systems, with hydrogen mass to blue luminosity ratio ( $M_{HI}/L_B$ ) values exceeding one in solar units, and active star formation. The *dwarf Elliptical* galaxies (dE), on the other hand, are usually gas-free, with ( $M_{HI}/L_B$ ) values substantially less than one. In most instances they are not actively forming stars, although their star formation histories are complex and varied. These dwarf galaxy types exhibit a morphology-density relation, in the sense that dE galaxies tend to be found in denser environments. For example, within the Local Group, the vast majority of the dE systems are found as companions to the Milky Way or M31, while the dIrr members are mostly relatively isolated.

In the Local Group there are also dwarf galaxies that are *transition-types*, systems that possess moderate amounts of gas ( $M_{HI}/L_B \approx 0.1$ – $0.5$ ) and a low-level of current or recent star formation within a dominant older population. We note in passing that the recently discovered distant Milky Way companion Leo T [5] is more likely a low luminosity dwarf irregular, than a genuine transition-type galaxy, as it appears  $M_{HI}/L_B$  for this dwarf exceeds one [5]. The relationship between these classes of dwarf galaxies remains controversial: e.g., [4] argue that the existence of an offset in the luminosity-metallicity relation between dEs and dIrrs indicates different evolutionary paths. They suggest that transition-type dwarfs are the progenitors of dE (dSph) systems, in the sense that in low density environments where ram-pressure stripping mechanisms are ineffective, transition-type dwarfs should be common [4].

One obvious way to test this suggestion is to investigate the properties of dwarf galaxies in environments beyond the Local Group. The Sculptor Group is a low density aggregation of galaxies ranging in distance from  $\sim 1.5$  to  $\sim 4$  Mpc. It contains at least five low-luminosity early-type dwarf galaxies. Their neutral gas content has been studied by [1], who found that four are likely

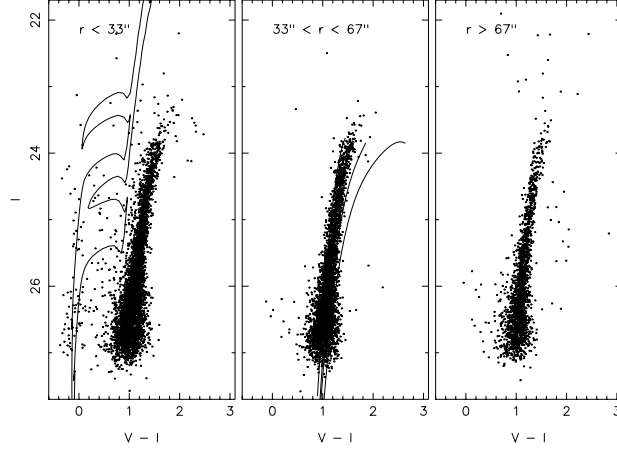
to be transition-type objects: the  $M_{HI}/L_B$  values are in the range 0.1–0.2 [1]. The fifth system, Scl-dE1, was not detected in HI and has  $M_{HI}/L_B < 0.04$  [1] as expected for a dE system. The transition-type nature of ESO410-005 and ESO540-032 is further supported by stellar population studies: both dwarfs show evidence for modest amounts of relatively recent star formation [7, 6]. We present here new data for ESO540-032: the optical observations reach considerably fainter than the ground-based study of [6], and the new HI observations have higher spatial resolution and signal-to-noise compared to [1]. The transition-type nature of this dwarf galaxy is confirmed.

## 2 Hubble Space Telescope Observations

HST/ACS observations of ESO540-032 were obtained in August 2006 with total integration times of 8960sec in the *F606W* (wide-*V*) filter and 6708sec in the *F814W* (wide-*I*) filter. The exposures used a standard dither pattern and were combined and corrected using the standard ACS data-processing pipeline. The DAOPHOT - ALLSTAR package [9] was used to determine photometry from the combined images. The calibration procedures outlined in [8] were then used to convert the photometry to the ACS VEGAMAG system and then to Johnson-Cousins *V* and *I* magnitudes.

The resulting colour-magnitude diagram is shown in Fig. 1, where the data have been separated into three radial bins based on distance from the galaxy centre. All three bins are clearly dominated by an old red giant branch (RGB) population, though as noted originally by [6] there is a small population of blue stars confined to the central regions of the galaxy. Application of a Sobel edge-detection filter to the RGB *I*-band luminosity function constructed from Fig. 1 places the RGB-tip at  $I=23.82\pm0.12$  mag. Using a reddening of  $E(V-I)$  of 0.03 mag and assuming  $M_I(\text{TRGB})=-4.05$  (e.g. [2]), this yields a distance of  $3.7\pm0.2$  Mpc, consistent with previous estimates. The luminosity of the dwarf is then  $M_V=-12.3$ , using the total apparent magnitude from [6]. Given the distance estimate, a comparison of the colour of the RGB with those of globular clusters provides an estimate of the mean metallicity of the dwarf. This value,  $[\text{Fe}/\text{H}] = -1.7 \pm 0.2$ , is strictly a lower limit, as at fixed abundance younger RGB stars are bluer. However, since the number of intermediate-age upper-AGB stars above the RGB tip in Fig. 1 is not substantial, the effect of any age difference on the mean metallicity value is likely to be small. With this metallicity and the absolute magnitude derived above, the location of ESO540-032 in the metallicity-luminosity diagram is reasonably consistent with the Local Group relation.

Knowledge of the distance also allows isochrones to be fitted to the stars to the blue of the RGB, the bluest of which undoubtedly represent a main sequence population. Using isochrones from [3] the age of the blue star population is potentially as young as 100Myr, perhaps less. Similar conclusions were reached by [6]. The isochrones also show that many of the stars that

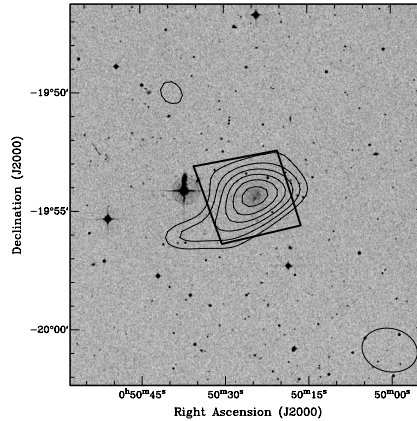


**Fig. 1.** Colour-magnitude diagrams for the Sculptor group transition-type dwarf galaxy ESO540-032. Note that the blue stars are found only in the central region. The isochrones shown in the left panel are for ages of 100 and 200 Myr and  $Z=0.001$ . The globular cluster giant branches shown in the middle panel are M15 ( $[\text{Fe}/\text{H}]=-2.17$ ), NGC 6752 ( $-1.54$ ), NGC 1851 ( $-1.36$ ), and 47 Tuc ( $-0.71$ ). Both the isochrones and the giant branches are plotted using an apparent  $I$ -band modulus of 27.87 and a reddening  $E(V-I)=0.03$ .

lie between the main sequence and the RGB, as well as the stars brighter and bluer than the RGB tip, can be understood as young stars in post main sequence phases of evolution. Clearly there has been an episode of star formation in ESO540-032 in the relatively recent past. Unfortunately, the small numbers of main sequence stars makes any attempt to measure the recent star formation history difficult – deeper observations are required.

### 3 Australia Telescope Compact Array Observations

Using the Parkes telescope [1] detected HI in the field of ESO540-032 at a velocity expected for objects in the Sculptor group. Using this velocity they were then able to use archival ATCA observations to demonstrate the detected HI was spatially coincident with the dwarf galaxy. The signal-to-noise of the archival observations, however, was low and the detection marginal. To confirm the detection, and particularly to establish the relative location of the peak of the HI with respect to the optical image, the galaxy was re-observed using longer integration times. Fig. 2 shows the results: HI is clearly detected and equally clearly, the HI distribution is centered on the optical centre of the galaxy. Further, given the beam size (cf. Fig. 2), there is no compelling evidence to suggest that the HI gas is more extended than the optical light distribution, which extends at least as far the edge of the ACS field. The total



**Fig. 2.** HI density contours superposed on a Digital Sky Survey image of ESO540-032. The lowest contour represents  $4 \times 10^{18} \text{cm}^{-2}$  ( $2.5\sigma$  above background) and the contour interval is  $2 \times 10^{18} \text{cm}^{-2}$ . The beam size of  $109'' \times 142''$  is shown in the bottom right corner. The quadrilateral outlined by the solid lines is the ACS field.

HI mass is  $9.1 \pm 1.7 \times 10^5$  solar masses, the peak density is  $15.2 \times 10^{18} \text{cm}^{-2}$  and the  $M_{\text{HI}}/L_B$  ratio is  $0.15 \pm 0.04$ , comparable to Phoenix [10].

## 4 Conclusions

The presence of a modest amount of recent star formation in an dominant old stellar population (age at least 6-8 Gyr given the comparative lack of upper-AGB stars), and the presence of a modest amount of gas, clearly confirm ESO540-032 as a transition-type dwarf galaxy in the Sculptor group (cf. [6, 1]). We have similar data for the other low-luminosity early-type dwarfs in this group – it will be interesting to see whether the analysis of these additional data supports the hypothesis of [4] that transition-type galaxies will be common compared to dE/dSph galaxies in low density environments.

## References

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